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STUDIES OF IONOSPHERIC PLASMA ELECTRODYNAMICS

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13. ABSTRACT *(Maximum 200 words)*

We have studied features of the high latitude ioosphere that help us to understand the response of the ionosphere-magnetosphere system to changes in the interplanetary medium. These changes begin principally with changes in the large scale ionospheric convection pattern. however, these changes subsequently change the distribution of ionization, which in turn changes the neutral atmosphere and the neutral and plasma temperatures.

At high latitudes we have studied the electrodynamics on the dayside where direct connection ot the solar wind is made with the Earth's magnetic field during times of southward IMF. We have also investigated the dynamics of the nightside where the response of the magnetospheric tail to substorms is probably most important.

In addition to our high latitude work we have continued an investigation of equatorial irregularities with emphasis on the dynamics of the plasma within them.

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STUDIES OF IONOSPHERIC PLASMA ELECTRODYNAMICS

Introduction

During this contract period our research effort has been focused principally on features of the high latitude ionosphere that help us to understand the response of the ionosphere-magnetosphere system to changes in the interplanetary medium. These changes begin principally with changes in the large scale ionospheric convection pattern. But these changes subsequently change the distribution of ionization which in turn changes the neutral atmosphere and the neutral and plasma temperatures.

At high latitudes we have studied the electrodynamics on the dayside where direct connection to the solar wind is made with the Earth's magnetic field during times of southward IMF. We have also investigated the dynamics of the nightside where the response of the magnetospheric tail to substorms is probably most important.

In addition to our high latitude work we have continued an investigation of equatorial irregularities with emphasis on the dynamics of the plasma within them

1. Electrodynamics in the Cusp

The ionospheric footprint of the cusp maps the region where direct electrical connection the interplanetary magnetic field is made and where energetic particles from the magnetosheath have direct access to the atmosphere. Over the years many signatures in measured parameters have been used to define the ionospheric footprint of the cusp. Enhancements in the airglow produced by the energetic particle precipitation [Sandholt et al., 1985], the energy spectrum of precipitating electrons [Newell and Meng, 1992] electric field structure associated with the so-called merging process at the nose of the magnetosphere [Baker et al., 1990] and shears in the bulk flow associated with changes in the magnetic field topology [Heelis et al., 1976] have all been used to define the cusp or boundaries of the cusp. A significant barrier to our understanding of the cusp lies in its dynamic nature. Since the location and extent of the cusp could change rapidly with time, a combination of measurement techniques is usually required to investigate its properties. The combination of ground based airglow measurements and satellite measurements of ion drifts and particles has allowed progress to be made. We were able to capitalize on an opportunity provided by the DMSP satellite as it traverses the cusp almost longitudinally in a matter of a few minutes. Ground based airglow data were able to establish the stability of the cusp in latitude at this time and thus a measure of the local time extent of the cusp is possible.

Figure 1 shows the observed convection signature and the shaded region where optical observations confirm the location and stability of the cusp.

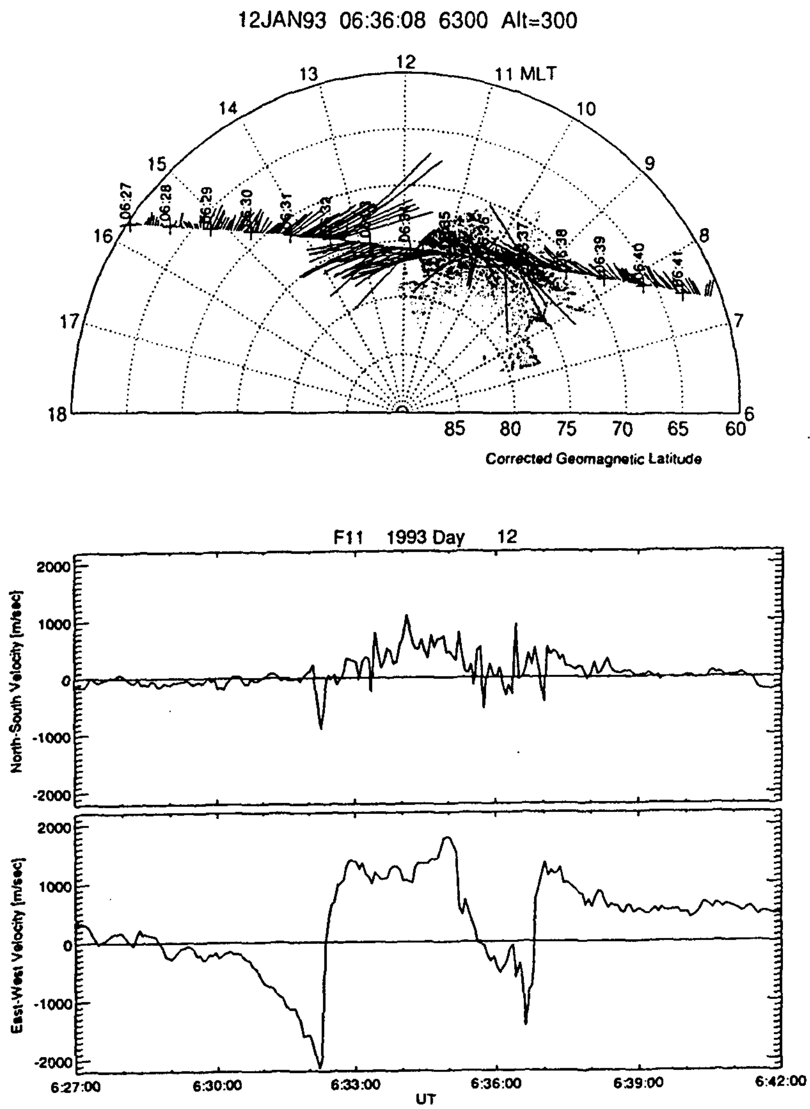

Figure 1. DMSP data recorded during a passage across the dayside cusp.

Baker, K. B., et al., Simultaneous HF-radar and DMSP observations of the cusp, *Geophys. Res. Lett.*, **17**, 1869-1872, 1990.

Heelis, R. A., W. B. Hanson, and J. L. Burch, Ion convection velocity reversals in the dayside cleft, *J. Geophys. Res.*, **81**, 3803, 1976.

Newell, P. T., and C.-I. Meng, Mapping the dayside ionosphere to the magnetosphere according to particle precipitation characteristics., *Geophys. Res. Lett.*, **19**, 609-612, 1992.

Sandholt, P. E., A. Egeland, J. A. Holtet, B. Lybekk, K. Svenes, S. Asheim, and C. S. Deehr, Large- and small-scale dynamics of the polar cusp., *J. Geophys. Res.*, **90**, 4407-4414, 1985.

2. Ionospheric Convection during Substorms.

With previous support from this contract we were able to continue work on an analytical description of the ionospheric convective flow from a solution of Laplace's equation. This expanding/contracting polar cap model originally developed by Siscoe and Huang [1985] has been extended to include flow regions on the dayside and the nightside through which plasma can enter and exit respectively. In the model used for this study, potentials across the dayside and nightside gaps are individually selected to provide a best fit for the observed convection signatures during a substorm period. The selected potentials then indicate the presence of an expanding or contracting polar cap. A schematic illustration of the model boundaries is shown in Figure 2. During an isolated substorm we find that the polar cap expands during the growth and expansion phases During the recovery phase the polar cap contracts due to the continued presence of reconnection in the tail.

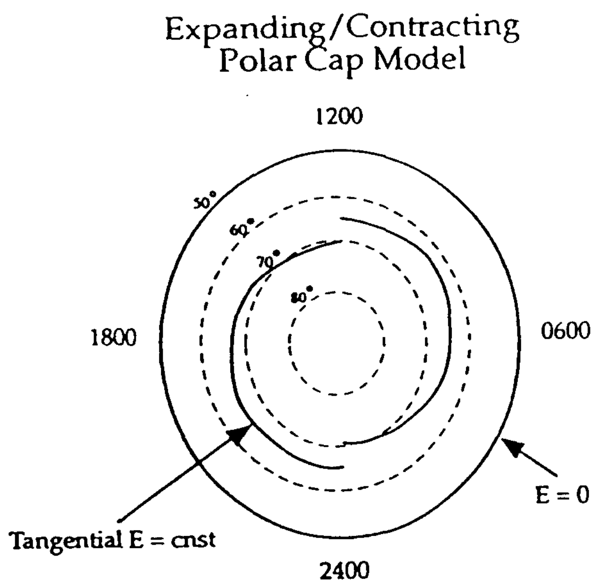

Figure 2. Configuration of the polar cap showing two expanding and contracting arcs that comprise the polar cap boundary.

Siscoe, G. L., and T. S. Huang, Polar cap inflation and deflation, *J. Geophys. Res.*, **90**, 543-547, 1985.

3. Fast Equatorial Bubbles

Equatorial irregularities frequently take the form of large scale depletions known as bubbles. These bubbles form just after sunset as a result of gravity wave seeding and subsequently rise under the action of the Rayleigh-Taylor instability. Under simple linear assumptions the velocity of plasma inside the bubble depends upon the ratio of the flux tube integrated conductivities inside to outside the bubble. Thus, for significant bubble depletions, very large upward flows could be observed relative to the more slowly moving background. Figure 3 shows observations of bubble plasma velocities in the topside ionosphere that are in excess of 2 km/s. Such large velocities are observed at 800 km altitude near 2100 hrs local time and are believed to coexist with the background plasma that is drifting upward under the influence of the post-sunset enhancement electric field. Under this influence the plasma will continue to accelerate until the apex height of the associated flux tubes rises above about 700 km. Then it will slow but still not reverse. Such findings have significant influence on both the evolution of bubble plasma and on the existence of large plasma gradients in the topside ionosphere.

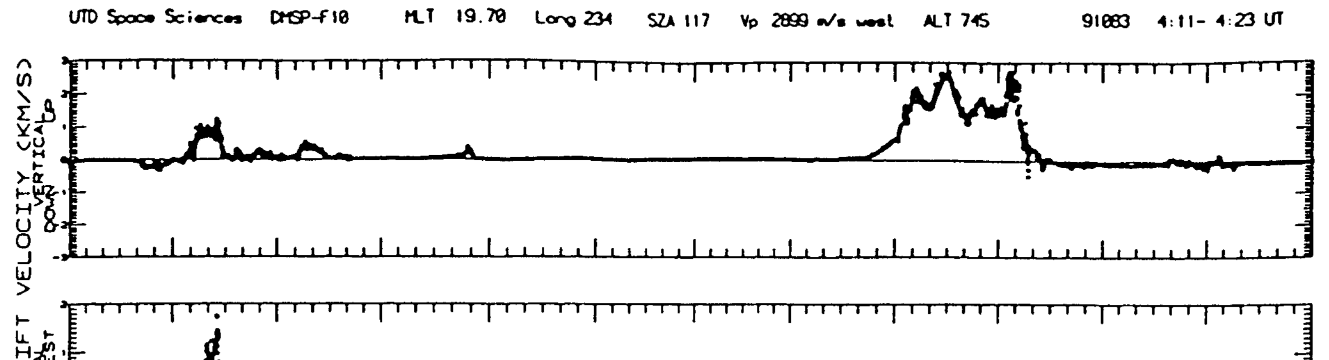

Figure 3. DMSP data indicating upward ion drifts in excess of 2 km/sec in equatorial plasma bubbles

Publications

The work described above has been systematically published in the leading journals in our field. Titles and abstracts of this published work are given below.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 102, NO. A3, PAGES 4765-4776, MARCH 1, 1997

How wide in magnetic local time is the cusp? An event study

N. C. Maynard,[1] E. J. Weber,[2] D. R. Weimer,[1] J. Moen,[3] T. Onsager,[4] R. A. Heelis,[5] and A. Egeland[6]

Abstract. A unique pass of the DMSP F11 satellite, longitudinally cutting through the cusp and mantle, combined with simultaneous optical measurements of the dayside cusp from Svalbard has been used to determine the width in local time of the cusp. We have shown from this event study that the cusp was at least 3.7 hours wide in magnetic local time. These measurements provide a lower limit for the cusp width. The observed cusp optical emissions are relatively constant, considering the processes which lead to the 630.0 nm emissions, and require precipitating electron flux to be added each minute during the DMSP pass throughout the local time extent observed by the imaging photometer and probably over the whole extent of the cusp defined by DMSP data. We conclude that the electron fluxes which produce the cusp aurora are from a process which must have been operable sometime during each minute but could have had both temporal and spatial variations. The measured width along with models of cusp precipitation provide the rationale to conclude that the region of flux tube opening in the dayside merging process involves the whole frontside magnetopause and can extend beyond the dawn-dusk terminator. The merging process for this event was found to be continuous, although spatially and temporally variable.

J. Geomag Geoelectr., 48, 915–923, 1996

The Nightside Ionosphere: Ionospheric Convection during an Isolated Substorm on October 21, 1981

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Substorms can occur in series such as during a geomagnetic storm or as isolated events. We have chosen an isolated substorm from the Dynamics Explorer-2 (DE-2) database and use the Expanding/Contracting Polar Cap Model to study the substorm-related ionospheric electric fields and polar cap dynamics. The isolated event of October 21, 1981 took place during several consecutive DE-2 passes which occur before the onset, just after the onset, during the substorm maximum, and during the recovery phase of the substorm. The polar cap expands during the growth and expansion phases and contracts little throughout the recovery phase. Tail reconnection, however, dominates the recovery phase. A total of 4×10^8 webers of open flux were reconnected during the recovery phase and removed from the polar cap.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 102, NO. A2, PAGES 2039–2045, FEBRUARY 1, 1997

Fast equatorial bubbles

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Abstract. Ion velocities associated with nighttime equatorial plasma depletions near 800 km altitude have been investigated utilizing data from the Defense Meteorological Satellite Program. Observations of upward ion drifts exceeding 800 m s^{-1}, within the depleted regions, are shown to have a strong dependence on solar zenith angle. Given the existence of bubble plasma, the probability of observing large upward drifts is as high as 40% just after sunset, when the solar zenith angle is 110°, but it decreases rapidly, falling below 5% for solar zenith angles above 140°. It is suggested that irregularity formation in the bottomside F region during a period of postsunset enhanced electric fields will cause magnetic flux tubes of depleted plasma to accelerate upward, reaching a velocity maximum at apex heights corresponding to the peak in the flux-tube-integrated conductivity of the background plasma. In the presence of a postsunset enhanced electric field, this peak may exist at apex heights above 500 km.